Building Retrofit – heating and cooling without electricity.

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"Around 80% of the population live in urban areas. While new buildings add at most 1% a year to the existing stock, the other 99% of buildings are already built and produce 27% of all carbon emissions. At least 80% of the current housing stock will still be standing in 2050. Therefore tackling its energy efficiency is vital to our future" (Power, A. 2005).

Topic Description

The housing estate stands responsible for a major part of the worlds increasing energy consumption; 42% of estimated greenhouse gas emissions are generated in the home. In Australia space heating and cooling and water heating account for two thirds of all household energy use (Australian Greenhouse Office 2005). This has not always been the case. Prior to electrical indoor air temperature control such as AC, buildings were designed as a response to their local climate. This paper examines non-electrical strategies for building heating and cooling, passive solar design, with a PV Trombe Wall retrofitted in to a Honey Storage building as an example to show the possibility to save energy.

1. Problem Description

With modern technologies such as AC, architecture tends to deny its local environment. Instead of taking advantage of natures own heating and cooling system; sun, wind, and thermal mass in materials, the natural elements are closed out and the choice of materials are based on aesthetics and "fashion" rather than thermal qualities. To compensate for uncomfortable temperatures, electrical heating and cooling equipment is added. Considering the unsustainable sources- and inefficient transport of energy, this is a major problem within the built environment. Singh, Manapatra and Atreya (2009) argue that energy efficient buildings have the potential to reduce carbon emissions by 60% or more. This number shows necessity of a change in the way we design and operate buildings.

2. Innovations and Concepts

Passive solar design includes a range of non-electrical heating, cooling and lighting strategies. Jie et al. (2006) argues that the basic principles in passive solar architecture is to size, orient and locate components to take maximum advantage of surroundings and climate to provide natural light and to stabilise indoor ambient temperatures in a controlled way. Mendler, Odell and Lazarus (2006) suggests that a holistic approach to ventilation, lighting and sun control in the design phase will lead to a more efficient end result. However, there are many strategies that can be used to retrofit a building. Some examples are buoyancy ventilation such as stack ventilation (Fig.1) and cool towers (Fig. 2). Other simple elements such as reflective insulation, shading and thermal mass can also easily be retrofitted into an existing building.

The PV Trombe Wall can also be retrofitted into a building. It operates with the same principle as the conventional Trombe Wall (Fig. 3), but has been altered to become more efficient by for example reducing heat loss on cloudy days and overheating during summer. The PV Trombe Wall system (Fig. 4), is composed of a five layered PV glass panel on which PV cells are affixed, a blackened wall acting as a thermal absorber and an air duct in between. During the day, sunlight shines through the glazing and hits the surface of the thermal mass, warming it by absorption. The air between the glazing and the thermal mass warms (via heat conduction) and rises, taking heat with it (convection). There are two air vents for winter heating and two air vents for summer cooling. For heating the external vents are closed and cold air is drawn from the house, warms up as it rises and let back into the house. At night, a one-way flap on the bottom vent prevents backflow of cold air. Heat stored in the thermal mass radiates into the living area. For cooling, the external vents are opened and as warm as air rises out, a suction of air is created through the room from an additional strategically placed vent. A layer of insulation and shading is added to prevent overheating through radiation (Elsevier 2008).

The PV Trombe Wall is used more on the domestic scale and in small-scale buildings. Because it needs sunlight it requires to be placed towards the sun and will therefor have little function in rooms placed at opposite side of the building. A solution to this could be a pipe system leading out from the PV Trombe Wall to distribute air into the building.

The PV Trombe Wall was installed in a Honey Storage Building and temperatures and energy consumption was measured. The results showed that most energy were saved during winter months, and even-though insulation was added during the summer, additional cooling was still required (Elsevier 2008). Perhaps the PV Trombe Wall could be more efficient if a phase change material was added on top of the wall. Instead of letting all air out, some of the air would pass through pipes of the phase change material to cool down let into the building.

3. Implementation issues

One of the issues with sustainability is public awareness and lack of knowledge. When there is an up front cost many people are driven away from sustainable solutions. There is a need to make people aware that the up front cost will be payed back. Mendler, Odell and Lazarus (2006) argues, "Sustainable design improves the value of buildings". They relate the value to amongst others;

1. The users are more satisfied and more productive; natural daylight and ventilation can give a 20% increase in productivity.
2. The building have a lower operation cost, and this cost can be multiplied with 10 to estimate the increased building value.

Another issue is the building industries' reluctance to explore and use other strategies. This is also often related to the up front cost. Government rebates and tax credit incentives could be a solution to this.

Mendler, Odell and Lazarus (2006) suggest educating the entire building team, from designers through to stakeholders, on sustainable solutions and the advantages of them. Knowledge and investigation on sun-angles, wind directions etc. to use this in the designing and building process is also an imperative. Perhaps by making sustainability and passive solar design an integral part of the studies of the built environment such as architects, engineers, and construction management, more sustainable solutions could be achieved, and in the future, it could become a natural part of the built environment.

Design is also an issue. By include non-electrical heating and cooling elements such as the PV Trombe Wall in the design one can make it aesthetically pleasing. Perhaps one can make a fashion of it by introducing art to the part that used to be glass with any thermal mass behind. This can be introduced on both the domestic and commercial stage. As mentioned, for the commercial stage and larger buildings more efficiency could be reached if piping systems could distribute the air around the building, and by adding a phase change material it could be made suitable for a greater variety of climates.

Sustainability issues

Elsevier (2008) states that estimated payback period is about 3,4 years. This means that the PV Trombe Wall is economically feasible both on domestic and public scale.

Depending what the PV Trombe Wall is made of, if the thermal mass and the glass is recycled, and where it is transported from, there will be embodied energy and pollution in relation to production and transportation. However, as research shows, there will be major savings of energy when installed, and there are no further running costs. In the case of the Honey Storage Building there was an annual energy saving of 3312kWh/year for heating in the winter months. An average carbon dioxide (CO2) equivalent intensity for electricity generation from coal is approximately 0.98 kg of CO2/kWh. This means that the reduction in CO2 emissions into the atmosphere by energy conservation due to retrofitting in the PV Trombe Wall is 3250 kg/year (Elsevier 2008).

Even though the PV Trombe Wall does not provide “Positive Development” on its own, it can be a great contributor to move away from buildings that rely on electrical heating and cooling systems, which again means that the PV Trombe Wall can contribute to move away from energy consuming buildings and the unsustainable sources of the energy.

Conclusion

Buildings rely on electrical heating and cooling systems, which are driven on unsustainable sources of energy. If the build environment could move back to buildings that cooperate with nature to use sun, wind and thermal mass, this problem could be reduced. There are many easy implementations to retrofit buildings to decrease energy use on heating and cooling such as shade, insulation and ventilation. One implementation that regulates the indoor air temperature is the PV Trombe Wall. In the case study of the Honey Storage the PV Trombe Wall alone was responsible for a decrease of 3250kg/year of CO2 (compared to have electrical cooling driven on coal). If the built environment could follow this example and move away from energy consuming buildings, we are one step along the road to achieve a deeper sustainability.

References

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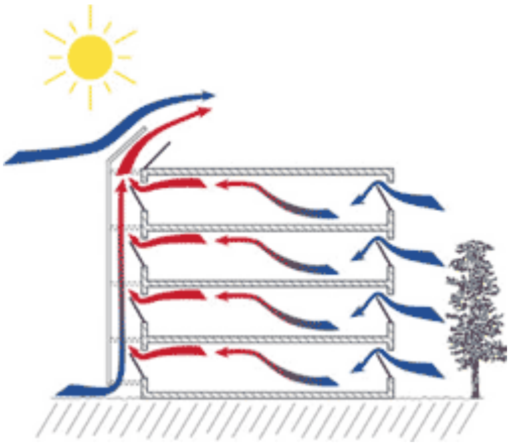
Fig. 1 Stack ventilation

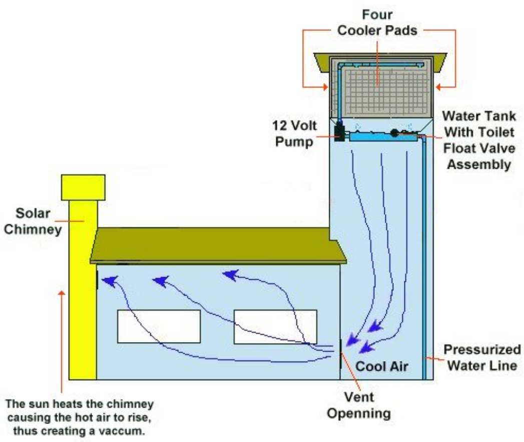


Stack Ventilation:
"In a similar way to smoke ventilation, the natural buoyancy of hot air is used to allow venting through high level vents. Replacement fresh air enters from the lower vents.

An advancement of this system is via a double façade. This works on the same principle as above (utilising both cross and stack ventilation) but also offers an ideal solution when the building is adjacent to roads and areas of high acoustic emissions".

(http://www.dyerenvironmental.co.uk/natural_vent_systems.html)

Fig. 2 Cooling Tower



This is the most common cool tower in use. As wind blows through the wet pads, the water evaporates and cools the air. Placing pads at the top of the tower usually requires appropriately 70-80 square feet of pads. With evaporative coolers you must leave an exit for the air to escape from your house. In normal water coolers a blower circulates the air, in this design wind and buoyancy will do the job for you. Standard cooler pads will work, but there are better, more efficient pads available that have less wind resistance . Of course these higher quality pads will cost more. Water must flow down the pads and air must pass through them in order to have the evaporation needed to cool the air. Vents must have a larger opening than those used with a forced air system because there is no pressurized fan blower in this system.

(http://www.i4at.org/lib2/aircool.htm)

Fig. 3 Conventional Trombe Wall

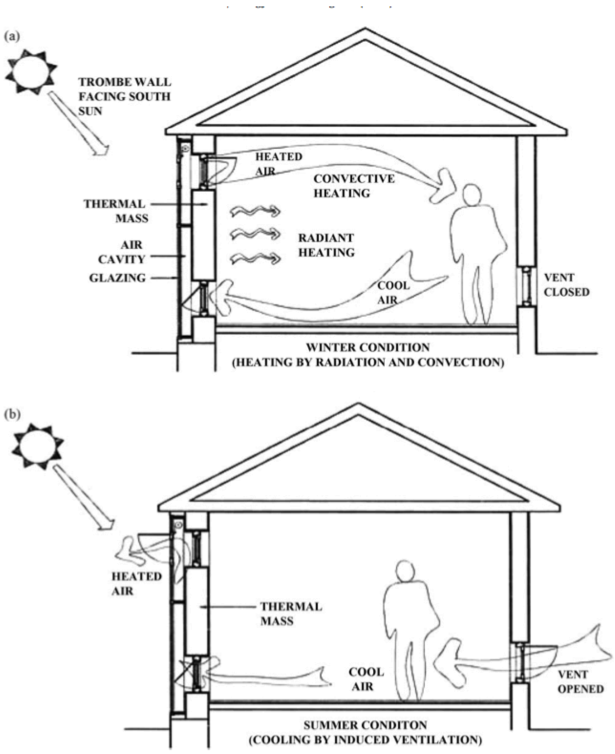


Fig. 1. A conventional Trombe wall during (a) winter and (b) summer [1].

(Elsevier 2008)

Fig. 4 PV Trombe Wall

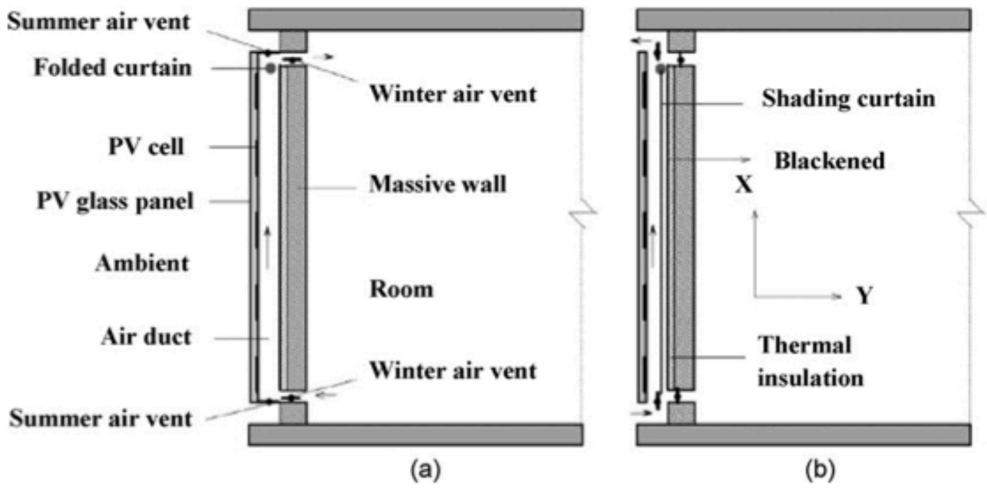


Fig. 2. PV-Trombe wall for (a) winter heating and (b) summer cooling [3].

(Elsevier 2008)